

New records of the genus *Cladonia* from Algeria

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ABSTRACT — Based on our studies of lichen-forming fungi in Kala National Park, Northeastern Algeria, four species, *C. cyathomorpha*, *C. dimorpha*, *C. monomorpha* and *C. subturgida*, were new reported for Algeria. Descriptions and taxonomic notes are provided; and a key is presented for all the *Cladonia* species known from Algeria.

KEY WORDS—*Cladoniaceae*, *Lecanorales*, Mediterranean Region, taxonomy

Introduction

The Mediterranean basin has been recognized as a global biodiversity hotspot (Médail & Quézel 1997). The diversity of lichen-forming fungi is well known in some Mediterranean countries, such as France (Ozenda & Clauzade 1970, Roux & al. 2014, 2017), Italy (Nimis 1993, 2016, Nimis & Martellos 2020, Nimis & al. 2018), Greece (Abbott 2009, Linda in Arcadia 2022), and Spain and Portugal (Llimona & Hladún 2001). However our knowledge of the diversity of lichen-forming fungi in North African countries is still poor.

Algeria is located in the Maghreb, bordered to the north by the Mediterranean Sea, to the east by Tunisia and Libya, to the southeast by Niger, to the southwest by Mali and Mauritania, to the west by Morocco and Western Sahara. It is the second largest country (2.4 million km²) from Africa. Four fifths of the territory are occupied by the Sahara desert. In the north of the country two

parallel mountain ranges, Tellian Atlas and High Plateau, form a natural barrier with the Sahara. In these regions, pine, cork oak, holm oak, carob forests, and a large number of shrubs, are the dominant vegetation.

Approximately 1100 taxa of lichen-forming fungi have been reported from Algeria (Amrani & al. 2018). Although in recent years several studies of lichen diversity have been carried out in certain protected areas (Rebbas & al. 2011, Serradj & al. 2013, Ali Ahmed & al. 2018), large areas of the country have not yet been explored, due to the scarcity of specialists in lichenology.

This study was carried out in the region of El Kala, considered as an Important Plant Zone (API) of Northeast Algeria, with a remarkable composition of rare, threatened, or endemic plants (Radford & al. 2011). It also offers an exceptional lichen flora. In the present study, we focus on *Cladonia*, a genus of lichen-forming fungi whose species are characterized by a dimorphic thallus, composed of a crustose or squamulose primary thallus and a fruticose secondary thallus. Most of the species are terricolous, growing on open areas with acid soils, although some develop on calcareous soils, and bases and trunks of trees (Ahti 2000, Ahti & Stenroos 2013, Burgaz & al. 2020). Twenty-five species of *Cladonia* have been reported from Algeria (Amrani & al. 2018), eight of them from the Edough Peninsula in Northeast Algeria (Ali Ahmed & al. 2018).

The aim of this paper is to report four new *Cladonia* species from Algeria, *C. cyathomorpha*, *C. dimorpha*, *C. monomorpha* and *C. subturgida*, and to put forward a key for all the *Cladonia* species reported from the country.

Materials & methods

Study Region

The specimens were collected between 2018 and 2019 from the El Kala National Park, in dune and mountain stations. This park is located in Northeast Algeria, at 36.71–36.95°N 7.72–8.62°E, with an altitude range from sea level to 1189 m. The park is limited to the north by a cordon of dunes bordering the Mediterranean Sea, to the east by the Algerian-Tunisian border, to the south by the mountains of Medjerda and to the west by the town of El Tarf and the vast marshes of Mekkada (Loukkas 2006). The region is characterized by a humid bioclimate, with average annual rainfall of 910 mm, and average annual minimum and maximum temperatures of 9°C and 30°C (Sarri & al. 2014).

Woodlands cover 70% of the total area of the park, including *Quercus canariensis*, *Q. coccifera*, *Q. suber*, *Pinus pinaster*, *P. halepensis*, and *Alnus*. Some areas are dominated by introduced species such as *Acacia mearnsii* and *Eucalyptus globulus*.

Morphological and chemical studies

The specimens were identified based on morphological characters (James 2009, Burgaz & Ahti 1992, 1994; Burgaz & al. 2020, Ahti 2000, Ahti & Hammer 2002, Pino-Bodas & al. 2012a, 2020, Ahti & Stenroos 2013). To confirm the identification of *C. subturgida*, ITS rDNA was sequenced using the protocols described in Pino-Bodas & al. (2020). The new sequence has been deposited in GenBank.

The descriptions of the species were based on: 10 specimens of *C. dimorpha*; 2 of *C. subturgida*; 1 of *C. cyathomorpha*; and 1 of *C. monomorpha*. The specimens were studied under stereomicroscope Leica EZ6 and Nikon Eclipse E400 microscope. Measurements were taken of length, width, and thickness of squamules and of the width, length, and thickness of podetia. Three squamules and three to five podetia per specimen were studied. Hand-cut sections of the squamules and podetia were made to study the microscopical features. Measurements of cortex, algal layer, medulla, stereome, and size of soredia were taken at 400×. Hand-cut sections of apothecia were taken to study and measure the ascospores at 1000×. In the text the measurements are indicated as (minimum–){X – SD}–{X + SD}(–maximum), where X is the arithmetic mean and SD the corresponding standard deviation, followed by the number of measurements. All the specimens are deposited in the Herbarium, Biology Department, Badji Mokhtar University, Annaba, Algeria (AAM), and a few duplicates at in the Mycology Herbarium, Royal Botanic Gardens, Kew, UK (K-M) or at the Herbarium, Departamento de Biodiversidad, Ecología y Evolución, Universidad Complutense de Madrid, Spain (MACB).

The secondary metabolites were studied using C, K, and Pd spot tests and by thin-layer chromatography (TLC) according to standardized procedures (White & James 1985, Orange & al. 2001), with solvent systems A and C.

Taxonomy

Cladonia cyathomorpha Stirt. ex Walt. Watson, J. Bot. 73: 156, 1935. FIG. 1A,D

PRIMARY THALLUS: squamulose, persistent, squamules 3–6 mm long × 1–3 mm wide (N = 3), margins rolled up and becoming more or less erect when dry; upper side grey to greenish, lower side white to dirty white, more or less veined, veins light to dark brown. ANATOMY OF SQUAMULES: (72–)79.16–101.19(–108) µm thick; cortex (19.2–)22.54–32.84(–36) µm thick; algal layer (16.8–)20.99–29.33(–31) µm thick; medulla (26.4–)29.88–45.18(–48) µm (N = 3). PODETIA: not very frequent, 4–6 mm tall, (0.41–)0.40–0.81(–0.97) mm wide (N = 3), scyphose, grey to greenish, surface smoothly corticate at the base, densely covered with small granules inside the scyphi, granules size (19.2–)24.71–52.53(–60) µm diameter (N = 22), occasionally scyphi with marginal proliferations. PODETIAL WALL: (117.66–)143.37–203.85(–226.7) µm; cortex (16.8–)21.98–37.72(–41.5) µm; algal layer (27–)34.65–57.25(–60.9) µm;

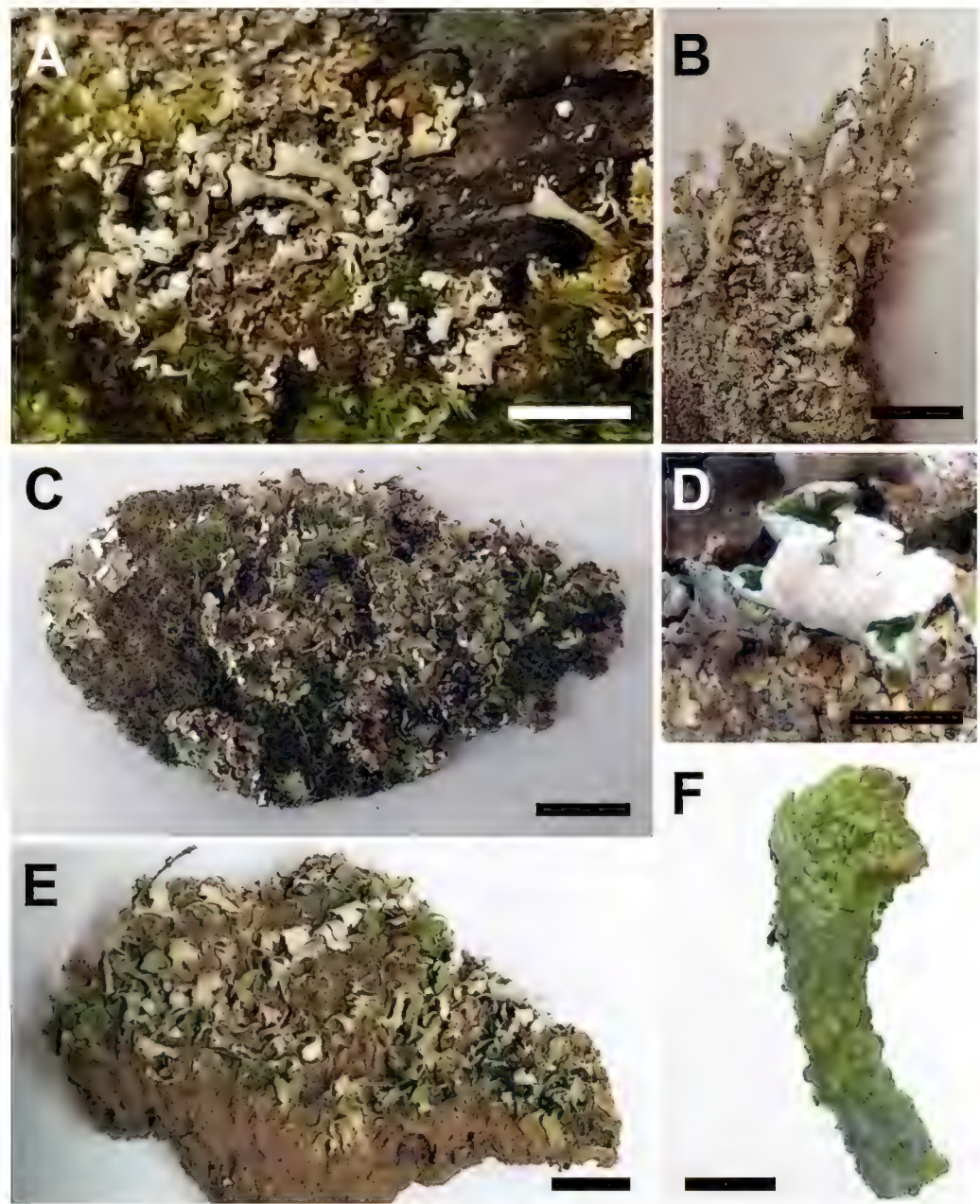


FIG. 1. *Cladonia cyathomorpha* (AAM-408): A. Thallus; D. Veins in the lower side of squamule. *Cladonia dimorpha* (AAM-371): B. Thallus. *Cladonia monomorpha* (AAM-179): C. Thallus; F. Podetium. *Cladonia subturgida* (AAM-409): E. Thallus. Scale bars: A, B = 5 mm; C, E = 10 mm; D, F = 1 mm.

medulla (44–)52.53–99.43(–112) μm ; stereome (9.6–)13.7–29.96(–36) μm (N = 3). APOTHECIA: very rare, brown, on the scyphal margin, ascospores simple, fusiform to ellipsoid, hyaline (4.8–)6.19–10.66(–11.52) μm long (2.88–)3.13–5.31(–5.76) μm wide (N = 10). PYCNIDIA: frequent on margins of scyphi, conidia not observed.

CHEMISTRY— C–, K–, Pd + red. Fumarprotocetraric acid complex.

HABITAT AND DISTRIBUTION—This species is not frequent in Algeria. Only one specimen has been found, growing on a tree trunk, in *Pinus pinaster* woodland,

at 4 m altitude. It is distributed in Western Europe, frequent in Mediterranean countries (Burgaz & al. 2020), reported also in North Europe, Macaronesia, and Argentina (Ahti & Stenroos 2013).

REMARKS—This is a new record for Algeria. It can be mistaken for *Cladonia humilis*, *C. pyxidata*, and *C. chlorophaea*, also reported in Algeria. *Cladonia humilis*, has shorter squamules, without veins or less marked, and farinose soredia. The primary thallus of *C. pyxidata* lacks veins in the lower side and has corticate plates inside the scyphi. *Cladonia chlorophaea* has corticate podetia with granulose soredia on the scyphi. The squamules of our specimen are slightly narrower than those reported by Burgaz & al. (2020), 5–8 mm wide, being similar in the rest of the characters.

SPECIMEN EXAMINED—ALGERIA. OUM TBOUL PROVINCE: National Park El Kala, Mechta Tonga, 36.8884°N, 8.4483°E, 4 m, sandy soil, 2.03.2019, M. Ali Ahmed & S. Boudiaf 408 (AAM, K-M 1434284).

Cladonia dimorpha S. Hammer, Mycotaxon 37: 339, 1990.

FIG. 1B

PRIMARY THALLUS: squamulose, persistent, squamules 4–6 mm long × 3–4 mm wide (N = 9), lobate and slightly dentate, rarely with black rhizines at margins, sometimes sorediate in the lower side. ANATOMY OF SQUAMULES: (100.8–)122.45–220.91(–285.4) µm thick; cortex (24–)27.91–50.09(–55.2) µm thick; algal layer (12–)16.67–69.07(–91.2) µm thick; medulla (36–)51.86–143(–156) µm (N = 9). PODETIA: frequent, ashy white to green, 3–16 mm tall, (0.39–)0.50–1.11(–1.31) mm (N = 9) wide at base, scyphose, scyphi 2–6 mm diam., always with branching proliferation at the margins. Surface smoothly corticate, cortex extending from the base to scyphi, sometimes with small squamules, sorediate at the scyphi (12–)14.18–25.16(–28.8) µm diameter (N = 51), and within scyphi. PODETIAL WALL: (115.2–)120.84–218.96(–252) µm; cortex (14.4–)29.55–66.81(–69.8) µm; algal layer (7.2–)11.95–45.65(–55.2) µm; medulla (40.8–)33.83–119.07(–144) µm; stereome (12–)10.74–18.06(–21.6) µm (N = 9). APOTHECIA: at tips of proliferation, brown or dark brown, ascospores hyaline, simple, oblong (8.64–)9.02–14.19(–16.32) µm long (2.88–)3.11–4.93(–5.76) µm wide (N = 25). PYCNIDIA: common, at the scyphal margins, globose and black, conidia not observed.

CHEMISTRY—Two chemotypes have been found. Chemotype I: C–, K–, Pd + red. Furmaprotocetraric acid complex, chemotype II: C–, K+ yellow, Pd+ red. Furmaprotocetraric acid complex, and atranorin. Chemotype I is the commoner.

HABITAT AND DISTRIBUTION—This species is not common in Algeria, growing on clayey and sandy soils, tree trunks and on mosses, in *Quercus suber*, *Pinus pinaster* woodlands, and *Eucalyptus globulus* plantation. It was collected in 3 localities in the National Park El Kala from sea level to 34 m altitude. The distribution of this species is not well-known, it has been reported from Western North America, Western Europe and Macaronesia (Pino-Bodas & al. 2017, Burgaz & al. 2020).

REMARKS—*Cladonia dimorpha* is similar in habit to *C. pyxidata* and *C. humilis*, but it has long, fissured marginal proliferations, similar to fertile podetia of *C. furcata*. When the proliferations are not developed (in juvenile podetia) the species is very difficult to identify (Ahti & Hammer 2002, Pino-Bodas & al. 2017). The identity of this species is uncertain in Europe, and Burgaz & al. (2020) considered that more studies are necessary to solve its taxonomic status. Our material is similar to prior published description (Burgaz & Ahti 2009).

SPECIMENS EXAMINED—**ALGERIA. OUM TBOUL PROVINCE: National Park El Kala.** Mechta Tonga, 36.8884°N, 8.4483°E, 4 m, sandy soil, 2.03.2019, M. Ali Ahmed & S. Boudiaf 370 (K-M 1434285), 371, 372, 373 (AAM) [Chemotype II]; **BRABTIA PROVINCE. Gantra Hamra**, 36.8642°N 8.3467°E, 34 m, clayey silt soil, 8.12.2018, M. Ali Ahmed & S. Boudiaf 254 (K-M 1434286), 255, 256, 257 (AAM) [Chemotype I]; **Cap Rosa**, 36.9491°N 8.2401°E, 10 m, clayey silt soil, 10.10.2019, M. Ali Ahmed & S. Boudiaf 632 (AAM), 633 (MACB 116475) [Chemotype I].

Cladonia monomorpha Aptroot, Sipman & Herk, Lichenologist 33: 273, 2001.

FIG. 1C,F

PRIMARY THALLUS: squamulose, persistent, squamules well developed, 2–5 mm long × 1–3 mm wide (N = 3), lobate, not much incised, erect but usually narrowly recurved at margin, upper side olive green, lower side white. **ANATOMY OF SQUAMULES:** (50.4–)58.84–162.64(–168) µm thick; cortex (9.6)10.99–45.23(–52.8) µm thick; algal layer (9.6–)11.6–39.14(–48) µm thick; medulla (21.6–)22.63–91.87(–98.4) µm (N = 3). **PODETIA:** small 2–4 mm tall, (0.31)0.35–0.47(–0.51) mm (N = 3) wide at base, scyphose, scyphi simple without marginal proliferations, green to brown, surface mostly corticate with bullate plates in the upper part and inside the scyphi. **PODETIAL WALL:** (122.4–)123.89–168.91(–172.8) µm; cortex (40.8–)41.08–60.68(–62.4) µm; algal layer (21.6–)24.51–36.93(–38.4) µm; medulla (28.8–)33.97–57.23(–60) µm; stereome (7.2–)10.73–25.75(–26.4) µm (N = 3). **APOTHECIA:** not observed. **PYCNIIDIA:** not common at the margin of the scyphus, dark brown. Conidia not observed.

CHEMISTRY— C–, K–, Pd+ red. Fumarprotocetraric acid complex.

HABITAT AND DISTRIBUTION—This is found on clayey silt soil in *Erica arborea* and *Calicotome villosa* shrubland, at 34 m altitude. This species has been previously reported from several Mediterranean countries and it is widespread in Europe (Aptroot & al. 2001, Burgaz & Ahti 2009).

REMARKS—The taxonomical status of *C. monomorpha* is controversial. Some authors consider it as a morphological variation of *C. pyxidata* (Ahti & Stenroos 2013, Burgaz & al. 2020), but according to Kowalewska & al. (2008) it is very distinct and deserves species level recognition. It can be distinguished from *Cladonia pyxidata* by the presence of bubbled and unflattened plates (Aptroot & al. 2001, Burgaz & al. 2020). The phylogenetic studies of *Cladonia* (Stenroos & al. 2019) showed that *C. pyxidata* complex needs more study. The specimen examined differ from the protologue (Aptroot & al. 2001) in having shorter podetia (up to 3 cm high in the original description).

SPECIMEN EXAMINED— ALGERIA. BRABTIA PROVINCE, National Park El Kala, Gantra Hamra, 36.8642°N 8.3467°E, 34 m, clayey silt soil, 8.12.2018, M. Ali Ahmed & S. Boudiaf 179 (AAM, K-M 1434287).

Cladonia subturgida Samp., Ann. Sci. Acad. Polytechn. Porto 13: 106, 1918.

FIG. 1E

PRIMARY THALLUS: squamulose, persistent, squamules large 2–9 mm long × 1–4 mm wide (N = 6), deeply lobed, upper side dark green to olivaceous, lower side white. ANATOMY OF SQUAMULES: (112.8–)115.06–188.02(–216) µm thick; cortex (21.6–)23.98–41.5(–48) µm thick; algal layer (12–)17.69–39.21(–40.8) µm thick; medulla (55.2–)63.41–117.27(–134.4) µm (N = 6). PODETIA: not observed. PYCNIDIA: black, frequent on upper side of the squamules, conidia not observed.

CHEMISTRY— C–, K+ yellow, Pd –. Atranorin and protolichesterinic acid.

HABITAT AND DISTRIBUTION— This is a terricolous species growing on clayey silt soil in a woodland of *Quercus suber* with *Pinus pinaster*, *Erica arborea*, *Calicotome villosa*, *Phillyrea angustifolia*, and *Helianthemum nummularium* at 100 m altitude. This species is known from Mediterranean and Macaronesian Regions (Kocakaya & al. 2018; Pino-Bodas & al. 2020).

REMARKS—This species has probably been overlooked. Although it has been found only in one locality, we think that it is widely distributed in Northern Algeria, since a recent study proved that *C. subturgida* is a common species in

the Mediterranean region (Pino-Bodas & al. 2020). Our identification has been confirmed by ITS rDNA.

It can be mistaken for *Cladonia firma* and *C. cervicornis*, other species with dominant primary thallus. *Cladonia cervicornis* has larger and sharply recurved squamules, brownish green on the upper side and pinkish brown on the underside, and generally contains only furmarprotocetraric acid. *Cladonia firma* has also thicker and larger squamules and the olive green color of the upper side usually with whitish apices, greyish brown in the lower side (Burgaz & al. 2020). The specimen fits to previous descriptions (Pino-Bodas & al. 2012b; Burgaz & al. 2020).

SPECIMEN EXAMINED— **ALGERIA. OUM TBOUL PROVINCE, National Park El Kala,** Haddada, 36.895752°N 8.617074°E, 100 m, clayey silt soil, 2.03.2019, M. Ali Ahmed & S. Boudiaf 409, 410 (AAM; Genbank OQ267627).

Key to *Cladonia* species of Algeria

1. Podetia richly branched, without cortex	2
1. Podetia absent or not richly branched or, if branched, with cortex	3
2. Branching pattern mainly dichotomous, UV+ white	<i>C. mediterranea</i>
2. Branching pattern mainly trichotomous, UV-	<i>C. arbuscula</i>
3. Squamules of primary thallus dominant, with or without podetia	4
3. Podetia dominant, primary thallus persistent or evanescent but never dominant	12
4. Growing on calcareous soil	5
4. Growing on acid or neutral soil or on wood	7
5. Squamules imbricate, forming a rosette	<i>C. pocillum</i>
5. Squamules scattered	6
6. Squamules small <4 mm long	<i>C. cariosa</i>
6. Squamules >4 mm long	<i>C. symphycarpa</i>
7. Squamules yellowish in the lower side	<i>C. foliacea</i>
7. Squamules with the lower side white, brownish or grey	8
8. Squamules Pd- or + yellow	9
8. Squamules Pd+ red	10
9. Squamules with coralloid margin, Pd + yellow	<i>C. parasitica</i>
9. Squamules without coralloid margin, fragile, Pd-	<i>C. subturgida</i>
10. K+ yellow, with pruinose margins	<i>C. firma</i>
10. K-, margins without pruina	11
11. Squamules small, with crenulate margin, lower side white	<i>C. caespiticia</i>
11. Squamules >5 mm, with entire margin, lower side brownish to grey	<i>C. cervicornis</i>
12. Podetia with scyphi	13
12. Podetia without scyphi	28
13. Podetia completely corticate	14

13. Podetia soresiate, granulose, squamulose or partially corticate	16
14. Podetia slender, >20 mm long, with narrow scyphi, some tips without scyphi, with lateral proliferations	<i>C. gracilis</i>
14. Podetia robust, with wide scyphi, with central proliferations	15
15. Podetia with more than 1 proliferation per tier, 1–4 tiers	<i>C. cervicornis</i>
15. Podetia with a single proliferation per tier, 1–7 tiers	<i>C. verticillata</i>
16. Podetia farinose soresiate	17
16. Podetia with granules, squamules, corticated plates or discontinuous cortex	25
17. Podetia slender, with narrow scyphi	18
17. Podetia short, with wide scyphi	19
18. Podetia unbranched, greenish with regular scyphi	<i>C. coniocraea</i>
18. Podetia simple or branched, whitish, with irregular scyphi and frequently marginal proliferations	<i>C. subulata</i>
19. Podetia mainly soresiate, with cortex restricted to the base	<i>C. fimbriata</i>
19. Podetia with cortex reaches the scyphal margin and soresia or granules in the upper part	20
20. UV+ blue	<i>C. grayi</i>
20. UV-	21
21. Scyphi with farinose soresia, <50 µm	22
21. Scyphi with granulose soresia, >50 µm	24
22. Podetia with marginal proliferations, proliferations longitudinally split	<i>C. dimorpha</i>
22. Podetia without marginal proliferations	23
23. Podetia with long stalk, K-	<i>C. conista</i>
23. Podetia without stalk, K+, rarely K-	<i>C. humilis</i>
24. Squamules with veins in the lower side	<i>C. cyathomorpha</i>
24. Squamules without veins in the lower side	<i>C. chlorophaea</i>
25. Podetia with discontinuous cortex and frequently with squamules	<i>C. ramulosa</i>
25. Podetia with bullate or flat plates on scyphi	26
26. Podetia with flat plates on scyphi	<i>C. pyxidata</i>
26. Podetia with bullate plates on scyphi	27
27. Squamules ± erect, scattered	<i>C. monomorpha</i>
27. Squamules imbricate, forming rosettes	<i>C. pocillum</i>
28. Podetial surface covered by numerous squamules	29
28. Podetial surface corticate or soresiate or with scattered squamules	32
29. UV+ White, podetia with open apex, forming funnels	<i>C. squamosa</i>
29. UV-, podetia with funnels or without funnels	30
30. Pd+ yellow, containing thamnolic acid	31
30. Pd+ red, containing fumarprotocetraric acid complex	<i>C. scabriuscula</i>
31. Podetia small, coralloid	<i>C. parasitica</i>
31. Podetia up to 50 mm, without coralloid appearance	<i>C. squamosa</i>
32. Podetia soresiate, with cortex restricted to basal part	33
32. Podetia completely corticate or partially decorticate but never soresiate	35

33. Pd- or Pd+ yellow, with red apothecia *C. macilenta*
 33. Pd+ red, with brown apothecia 34
 34. Podetia greenish, up to 25 mm long, unbranched *C. coniocraea*
 34. Podetia grey, up to 45 mm long, well developed podetia with antler-like
 branching pattern and some podetia with scyphi *C. subulata*
 35. Podetia unbranched or branched near the tips, partially decorticate with
 longitudinal fissures 36
 35. Podetia branched, completely corticated, without longitudinal fissures 37
 36. Squamules small <4 mm long, podetia richly fissured *C. cariosa*
 36. Squamules >4 mm long, podetia more robust, with few fissures .. *C. symphycarpa*
 37. Podetia with white areoles *C. rangiformis*
 37. Podetia without areoles *C. furcata*

Acknowledgments

We thank the Ministry of Higher Education and Scientific Research (MESRS) and the General Directorate of Scientific Research and Technological Development (DGRSDT) of Algeria for the financial support of this study. We also thank the National Park of el Kala (PNEK) for its cooperation and particularly to Mr. Grira Abdeslem (Senior Forest Inspector), for his invaluable assistance in the field. R. P-B was supported by Atracción de Talento program (2020-T1/AMB-19852). We are grateful to Prof. Ana Rosa Burgaz, Prof. Teuvo Ahti, and Dr. Mustafa Kocakaya for their valuable comments to improve the manuscript.

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